UC-NRLF
B 3 018 813
TJ
7
M3
V.79-84

MACHINERY'S REFERENCE SERIES

EACH NUMBER IS ONE UNIT IN A COMPLETE LIBRARY OF MACHINE DESIGN AND SHOP PRACTICE REVISED AND REPUBLISHED FROM MACHINERY

No. 79

A Dollar's Worth of Condensed Information

Locomotive Building

By RALPH E. FLANDERS

PART I

MAIN AND SIDE RODS

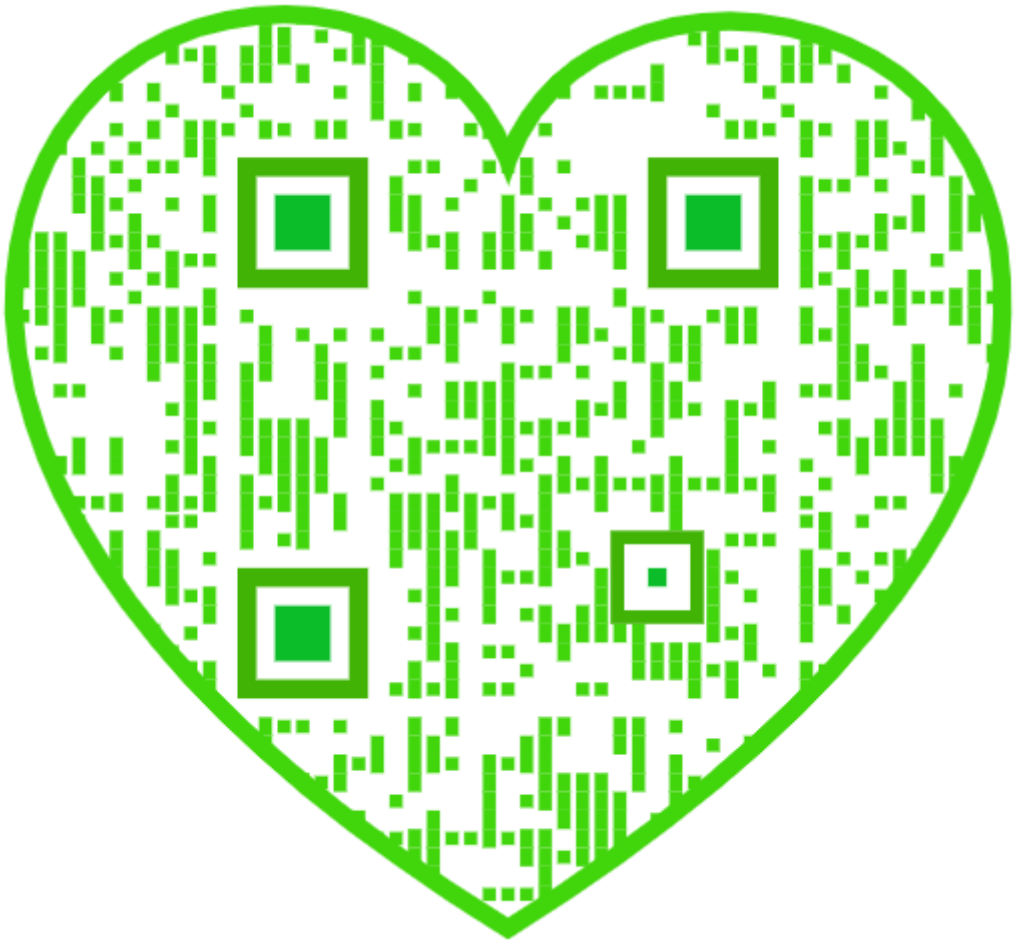
Price 25 Cents

CONTENTS

Shop Practice from the Juniata Plant - - - - 3
Roughing Operations on the Main Rod - - - 5
Laying-out and Finishing the Body of the Rod - - 7
Working out Jaws, Key-slots, etc. - - - - - 13
Bench Work on the Main Rod - - - - - 18
Design of Side Rods - - - - - - - - 19
Machining and Laying-out Rod Forgings - - - 21
Working out Holes and Openings - - - - 23
Operations on the Intermediate Side Rod - - - 29

The Industrial Press, 49-55 Lafayette Street, New York
Publishers of MACHINERY

COPYRIGHT, 1911, THE INDUSTRIAL PRESS, NEW YORK



MACHINERY'S REFERENCE SERIES

EACH NUMBER IS ONE UNIT IN A COMPLETE LIBRARY OF MACHINE DESIGN AND SHOP PRACTICE REVISED AND REPUBLISHED FROM MACHINERY

NUMBER 79

LOCOMOTIVE BUILDING

By RALPH E. FLANDERS

PART I

MAIN AND SIDE RODS

CONTENTS

Shop Practice from the Juniata Plant - - - - 3
Roughing Operations on the Main Rod - - - 5
Laying-out and Finishing the Body of the Rod - - 7
Working out Jaws, Key-slots, etc. - - - - 13
Bench Work on the Main Rod - - - - - 18
Design of Side Rods - - - - - - - - 19
Machining and Laying-out Rod Forgings - - - 21
Working out Holes and Openings - - - - 23
Operations on the Intermediate Side Rod - - - 29

Copyright, 1911, The Industrial Press, Publishers of MACHINERY, 49-55 Lafayette Street, New York City

LOCOMOTIVE BUILDING

MAIN AND SIDE RODS

Altoona is the focus of railway activity in western Pennsylvania. It forms the terminal of the Eastern and Western Pennsylvania Divisions, and there is scarcely a moment of the day when trains are not arriving or departing. The density of the traffic is best realized, perhaps, by sitting on the slope of the mountain-side above the Horseshoe Curve and watching the trains slowly panting upward or carefully sliding down the heavy grade. Apparently there is not an hour of the twenty-four, when one or more trains are not visible from this point. The sound of laboring locomotives and clanking couplings ceases not by day or night, year in or year out.

Aside from its importance as a division terminal, the town is still further distinguished by being the location of an immense system of railroad shops. It has, in fact, probably the largest railroad population in the world, numbering about seventy thousand inhabitants. The only other business of any size in the place employs not over one thousand workmen. All the miscellaneous industrial activities, such as those of the storekeepers, doctors, street-car employes, policemen, preachers, etc., must be credited to the railroad, as they serve the railroad employes, and without them they would be out of work. The Pennsylvania Co. has here an immense locomotive repair shop, a locomotive testing plant, car shops, and foundry; and a locomotive building plant at Juniata, a suburb toward the east. It is the practice in this latter shop which will be described in the following.

Shop Practice from the Juniata Plant

At the Juniata shops are built all the passenger engines for the Pennsylvania Railroad, and many of the freight engines as well. It takes a system the size of the Pennsylvania to build locomotives in sufficient quantities to make a shop of this kind profitable or possible. As it is, the types have been standardized and the work has been brought down to a manufacturing basis. The extent to which the interchangeable idea has been carried out would seem incredible to a mechanic not familiar with locomotive building, or familiar only with old-fashioned practice in that work.

In the present part of the complete treatise on locomotive building contained in MACHINERY'S Reference Series Nos. 79 to 84, inclusive, attention will be given especially to the making of the main and side rods. The separate operations are comparatively simple and may be shown readily by photographs. Many of them are ingenious, however, and some of them have highly suggestive value for similar work in other lines.

The rods chosen for illustration are those for a heavy consolidation freight locomotive. A drawing of the main rod is shown in Fig. 3.

347630

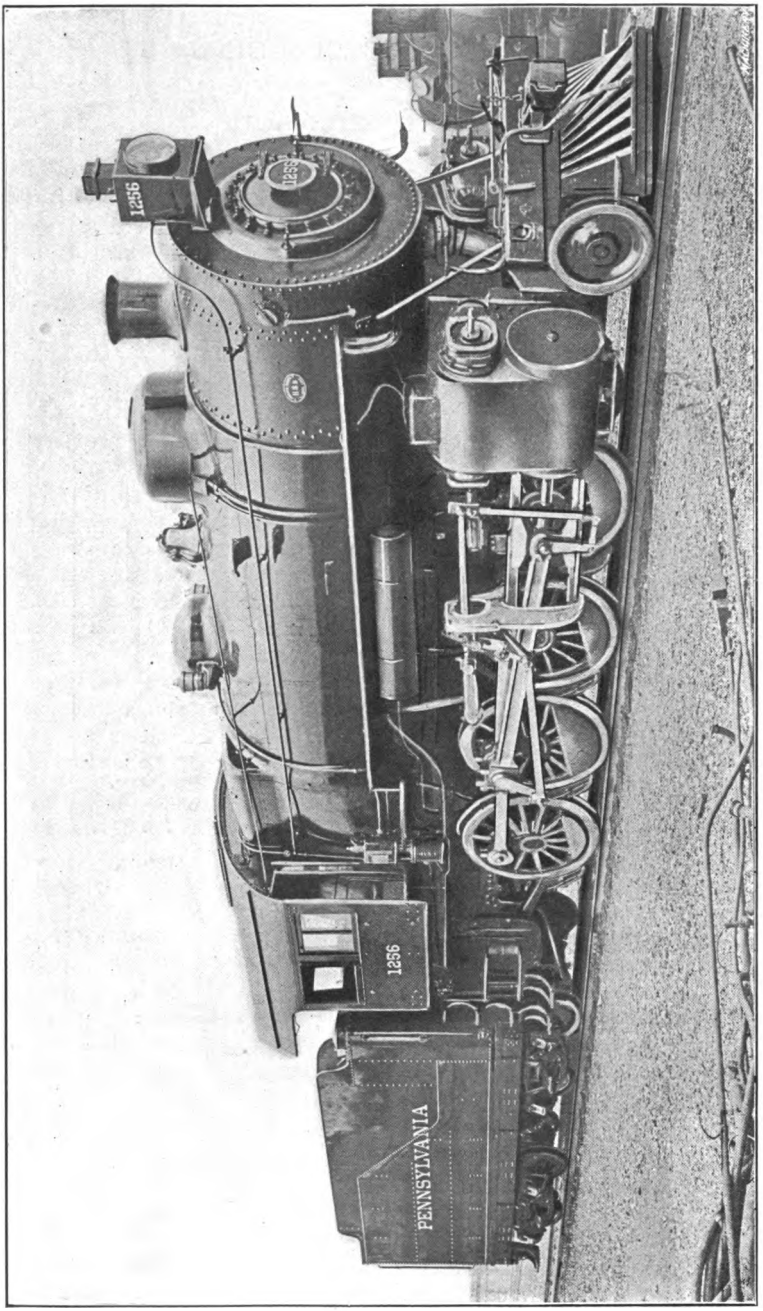


Fig. 1. Type H-8-B Consolidation Freight Locomotive built for the Pennsylvania Railroad at the Juniata Shops, Altoona, Pa.

It will be seen to differ radically in some particulars from the usual design. While the cross-head end is of familiar construction, the rear end catches the eye at once in looking at the finished locomotive. This is due to the placing of the key at the outside end of the rod. A rod made like this has an unfamiliar appearance, but its advantages grow on the beholder as he looks at it.

The construction is exceedingly simple, requires considerably less machining and a much smaller number of bolts and other small parts. It would seem to be secure as well. It will be noted that the key has a projecting lip at its lower end, which interlocks with a notch cut in the lower end of the bolt. This, in connection with the lock nuts on the bolt and the groove provided for the point of the set-screw in the key, makes it practically impossible for anything to get loose and fly out. To have this happen, the key set-screw would

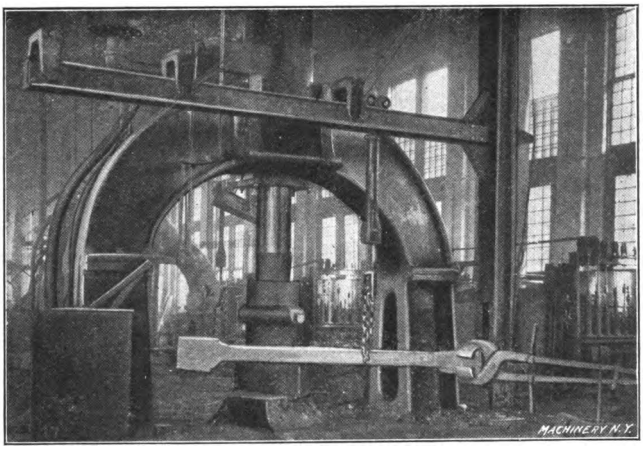


Fig. 2. Finishing the Main Rod Forging under the Steam Hammer

have to be unscrewed, or the point broken off; the cotter pin for the lock nuts on the bolt would have to be sheared; both nuts would have to be loosened and fall entirely off; and then both bolt and key would have to be thrown out at the top of the opening. It will be noted that the channeling is parallel. This permits the operation of cutting it out to be performed at one setting for each side. The flanges of the section are thickened at the rear end, giving the necessary increase in strength.

Roughing Operations on the Main Rod

Fig. 2 shows the blank for the main or connecting-rod in the forge shop. This treatise deals with the machining operations particularly, so the forging will not be elaborated on. The picture is interesting, however, in showing the type of equipment provided in this plant. Attention should be called to the large, airy room and the fine lighting. The completed forging is shown in Fig. 4 mounted on the scales. The weight of the particular one shown was 1,985 pounds. This

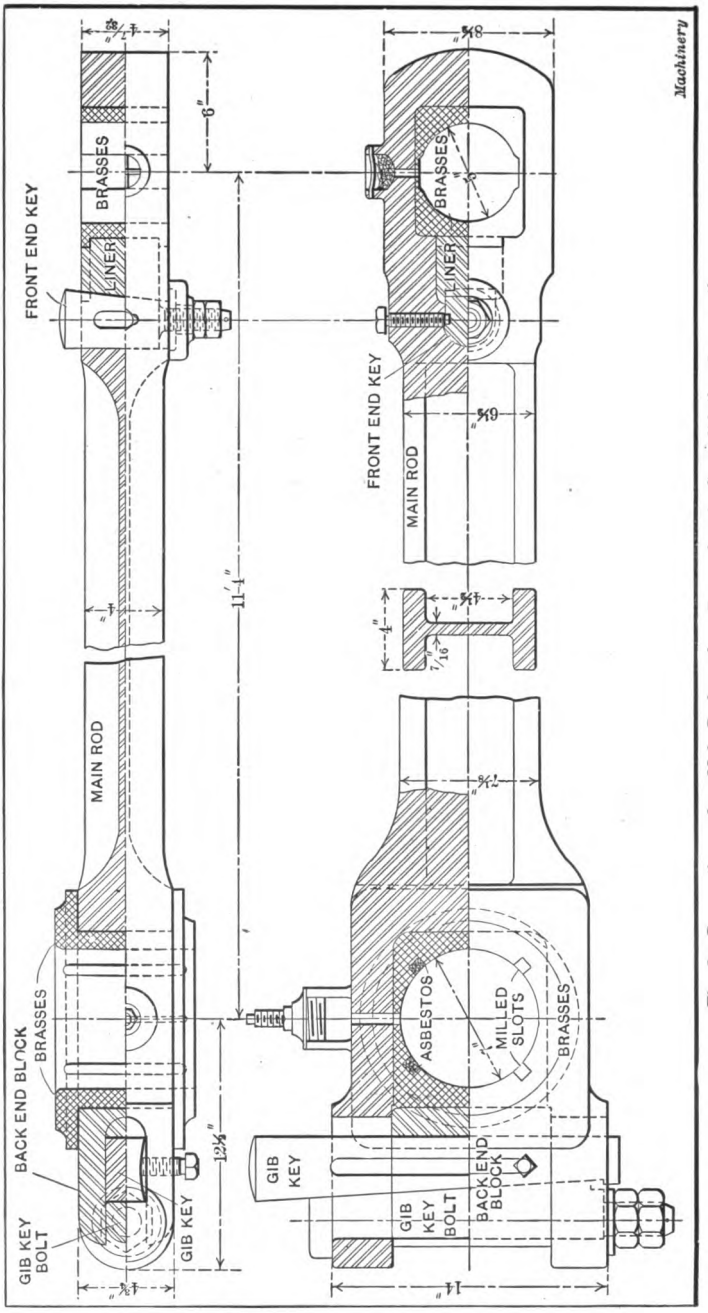


Fig. 3. Connecting-rod or Main Rod used on Pennsylvania Consolidation Locomotive

should be noted, as later on figures will be given to show the amount of metal removed in the different machining operations. It may be mentoned that the main rods, and all other parts of the locomotive, for that matter, look very much larger on the floor of the shop than they do when seen in place on the finished machine as it stands on the track. This ton-weight of forged steel is a very imposing piece of metal, indeed.

The first shop operation is that of planing the sides, top and bottom of the two heads of the main rod. The sides, in this operation, are planed down to size while the top and bottom are roughed only, these surfaces being of complicated form as may be seen from Fig. 3.

These cuts are taken on a planer of special design, widely used for this work. As best seen in Fig. 5, it has two sets of housings and cross-rails. Each set it provided with two tool heads on the cross-rail and two side heads, making eight tools available for simultaneous working. In the case shown all eight tools are at work.

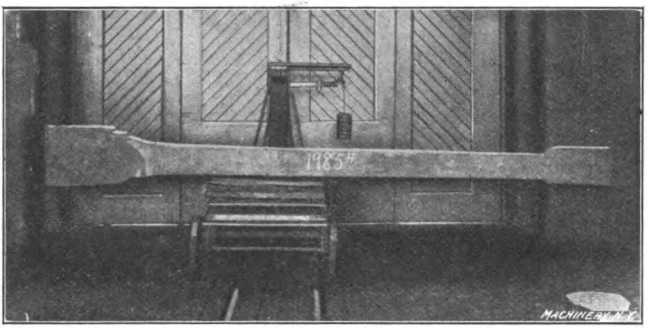


Fig. 4. Weighing the Rough Main Rod Forging

The table of this machine is not provided with a quick return, since the tools on one end cut in one direction, while the others cut on the back stroke. The housings at the right of Fig. 5 are adjustable along the length of the bed to agree with the length of rod being machined, thus adapting them for intermediate and end rods as well as for the long connecting-rods here shown. Fig. 6 shows a rear view from one end of the machine, showing four of the tools at work. The four at the other end are set in similar positions.

After machining one face and one edge at each end, as shown in Fig. 6, the rods are turned over onto these machined surfaces to permit the finishing of the other face and other edge of each. The methods of holding the work are of the simplest, being those used in standard planer practice. The rough planing of these surfaces leaves the rods in a condition to be clamped to the table and to each other on machined surfaces for subsequent operations.

Laying-out and Finishing the Body of the Rod

The rods are now taken from the planer and placed on horses on the open floor, where a workman lays the templet on each of them

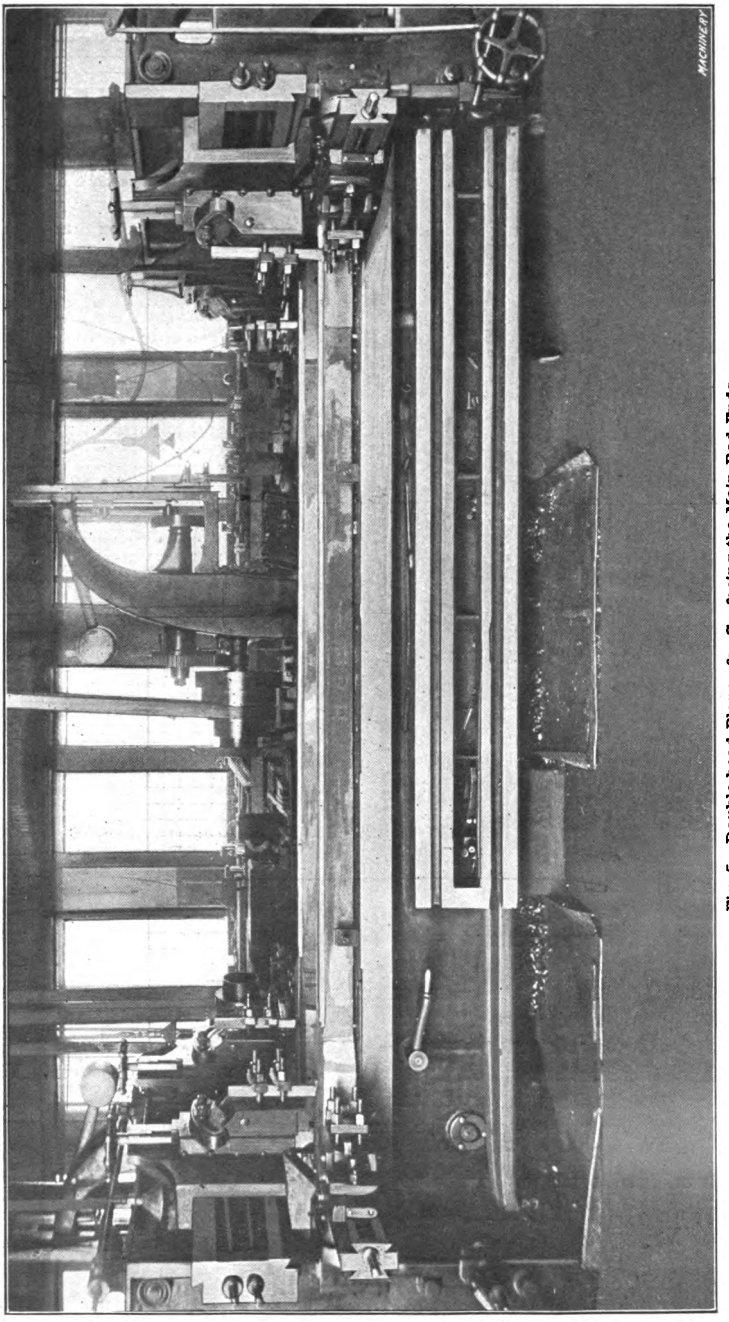


Fig. 5. Double-head Planer for Surfacing the Main Rod Ends

and scribes around it, on the planed faces of the two heads, the outline to which to finish the rod. Guided by these lines he prick-punches the centers for the various drilling operations required in working out the open and closed ends of the rod, and in machining the slots for the keys, bolts, etc. The laying out for all subsequent operations is all done at this time. By scribing from a templet in this way, assurance is given that the forging will finish out to the required size, and the work of taking measurements in machining is greatly reduced.

Fig. 7 shows the next machining operation, which is that of milling the top and bottom of the I-beam section of the rods. This is done, as shown, in a heavy slab milling machine with inserted tooth cutters, to which reference will be made in another part of this treatise. (See

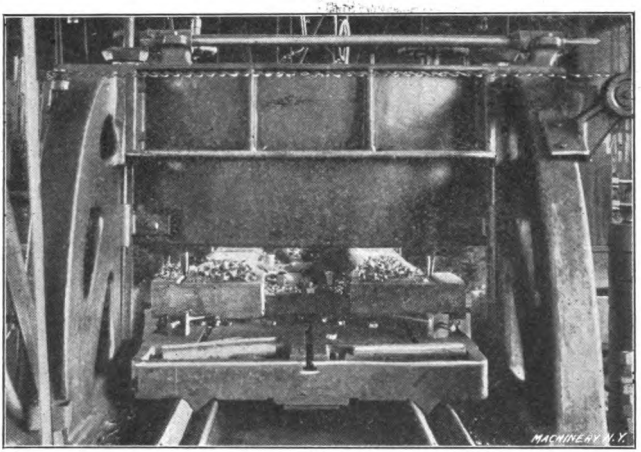


Fig. 6. Rear View of Planer showing Four Tools at Work on One End of Two Main Rods

MACHINERY'S Reference Book No. 82, Locomotive Building, Part IV.) Four of the forgings are mounted in place on the machine at a time. The ends of each rod are blocked up to bring the surface to be milled horizontal and at the proper height, as indicated by the scribed outline on the work.

It will be noted that piece No. 2 shows evidence of having got into difficulties. The distortion shown, however, is evidence of remedial action, instead of being the original cause of the trouble. The workman found, in lining this piece up on the planer in Fig. 5, that there was not stock enough to finish out the open end of the rod to the full width. It was, therefore, sent back to the shop and swaged out in the center, as shown, which widened it to the required dimensions. The reduced portion in the center comes in the part which is cut out to receive the brasses, so that it still permits the head to be finished out to the required dimensions. The kind and amount of chips produced in this operation give evidence of the size of cuts taken on locomotive work in this shop. A copious supply of lubricant is, of course, brought to the cutting edges.

After milling each of the straight sides of the rods, as shown in Fig. 7, the operator works out, so far as he can, the outline of the heads at both ends as scribed by the templet. This is done by raising or lowering the cross-rails by hand as the table is fed past under the cutters, following the scribed line and working out the metal close to it. This operation naturally requires considerable skill on the

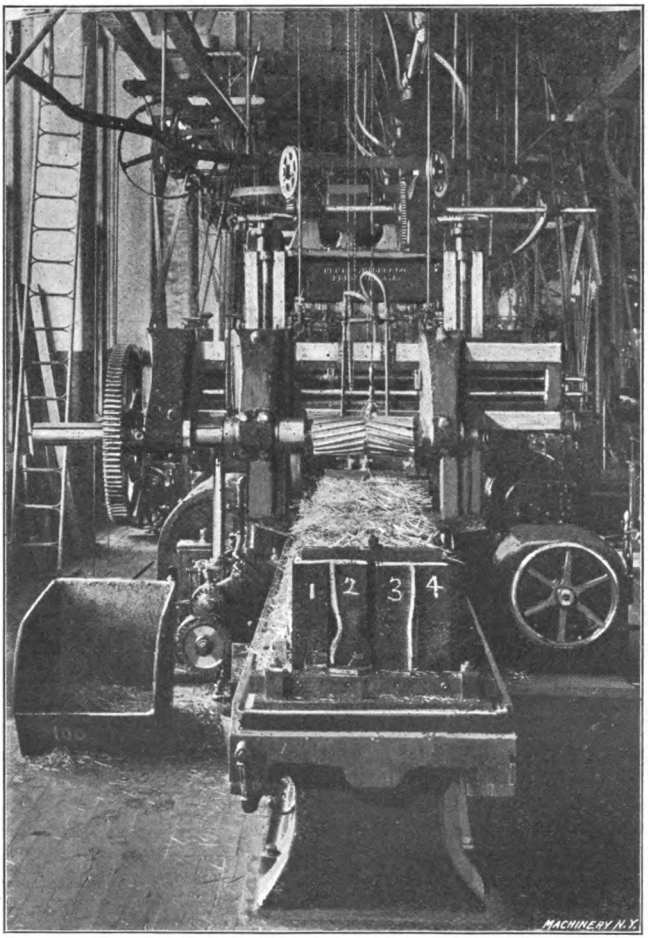


Fig. 7. Finishing the Top and Bottom Edges of the Main Rods in the Slab Milling Machine

part of the operator in following the line as closely as possible without breaking through it. The result of his skill is shown in Fig. 10, where the forging, as it looks after this operation, is shown on the scales. It will be noted by comparing this with Fig. 4 that 485 pounds of metal have been removed so far.

The I-beam section has next to be formed in the body of the rods by the milling of channels on each side. This operation is shown in progress in Fig. 8. The same machine is used as shown in Fig. 7, using inserted tooth cutters of the proper dimensions with corners rounded to the radius of the inside edges of the channel. Two rods are laid on the table side by side, held by suitable stops and clamps.

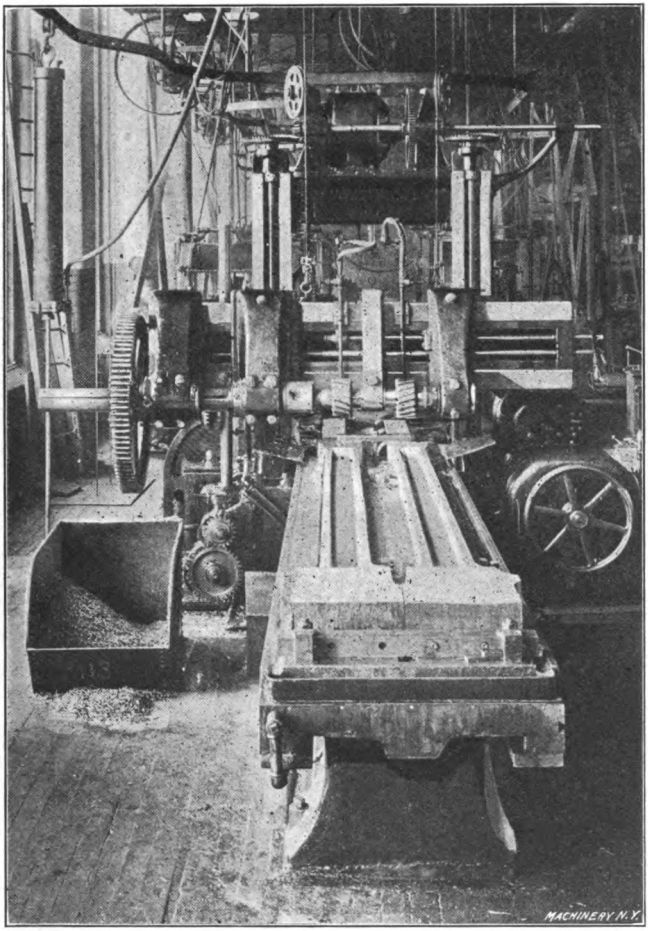


Fig. 8. Channeling Operation performed with Inserted Tooth Cutter

The cutters for this operation are 8¾ inches in diameter, and they revolve at 36 revolutions per minute, giving a surface speed of 82 feet per minute. The table feed is 1⅝ inch per minute. Two cuts are taken over each channel to bring it down to depth, the cut being 4½ inches wide and about ⅞ inch deep for each cut and cutter.

The supplementary support for the cutter arbor between the two cutters was no part of the original equipment, being added in the shop. It was found to greatly increase the capacity of the machine. It is only in the past decade that mechanics have discovered how important in the matter of production, is a support for the tools and the work rigid enough to prevent the harmful vibration and chat-

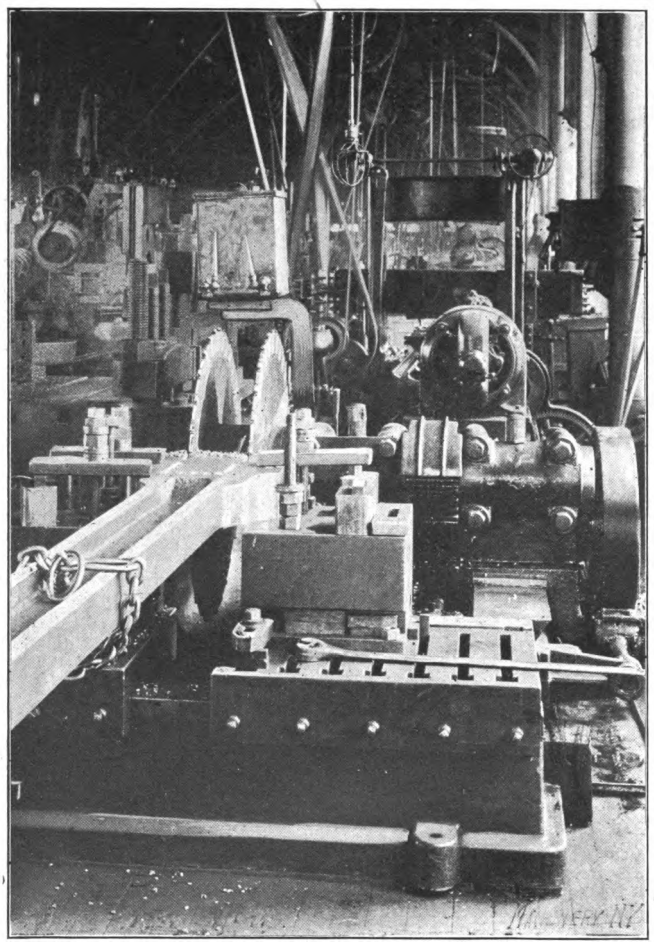


Fig. 9. Cutting out the Jaws for the Open End of the Rod in a Double-blade Sawing Machine

tering, which destroys the edges of cutting tools. The amount of metal removed in the operation shown in Fig. 8 is something over 500 pounds for each rod. The rigidity of the machine, the design of the cutters, and the proper relation between surface speed, feed, and depth of cut has a great deal to do with the efficiency obtained.

Working out the Jaws, Key-slots, etc., of the Main Rod

The rods are now taken to the drill press to drill the holes mentioned in the operation of laying out the work with a templet. For the rear or large end of the connecting-rod, the block taken out in forming the jaws is not removed entirely by drilling. As shown in Fig. 9, this block is cut out by a double sawing machine, the drill

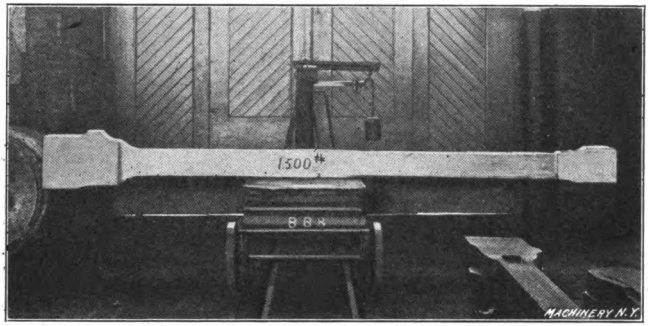


Fig. 10. The Main Rod Roughed Out

holes being used beyond the extreme depth to which the saws can enter. The outer end of the rod is supported on a horse in this operation, remaining stationary, since the feed is applied to the head on which the saws are mounted. These saws are of the inserted tooth type.

Fig. 11 shows the condition of the rod at the end of the operation shown in Fig. 9. It also shows the various holes drilled from the

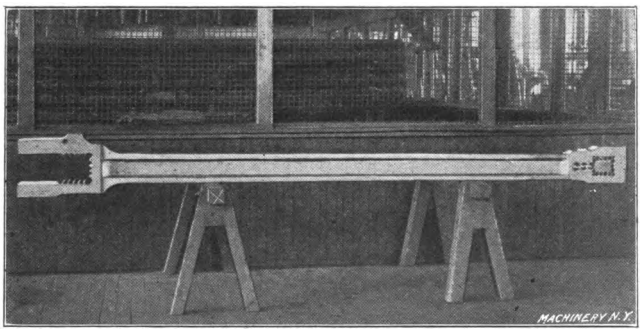


Fig. 11. The Main Rod ready for the Slotting Operations

lay-out provided by the templet. It will be noted that holes of various diameters are used. At the large end the large holes at the bottom of the jaws are properly located and of the proper diameter to furnish the rounded surface to which the inner corners of the opening are finished. In the same way the corner holes of the opening at the small end and the large holes in the key-slot are properly located and sized for finishing at these points. This accuracy in the laying

out and drilling of these holes simplifies the finishing operations in the slotting machine very much.

Fig. 12 shows the slotter at work on the rear end of the rod. A tool is used having cutting edges rounded to the radius of the corners

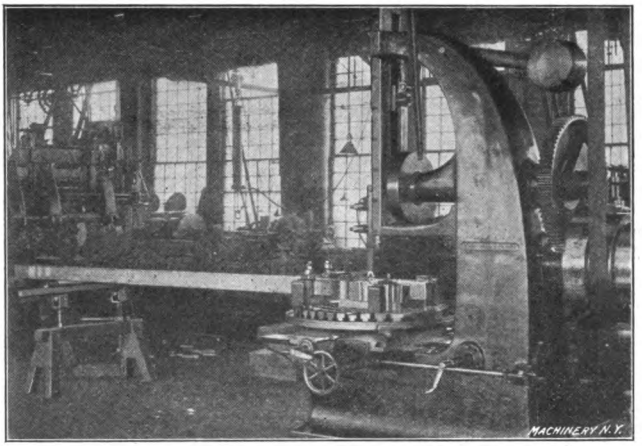


Fig. 12. Finishing the Open End on the Slotting Machine

of the opening, so as to join easily onto the radius produced by the drill holes. Comparatively simple outlines are required, as is shown plainly in Fig. 3. The lines scribed by the templet furnish the guide to the operator in this operation. The same cuts for the

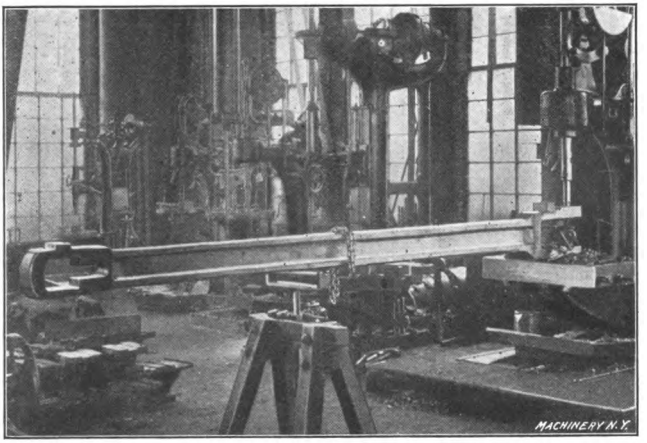


Fig. 13. Drilling the Hole for Keybolt Slot

small end of the rod are shown in progress in Fig. 14, which more plainly shows the form of tool used. This is provided with top rake as shown, and will cut when feeding in all four directions. A rubber tube for the lubricant is brought down close to the cutting point.

Fig. 12 and, later on, Figs. 25 and 31, show an interesting form of cutter support for heavy over-hanging work of this kind clamped to the slotting machine table. A horse or trestle is provided with a pair of leveling screws, each supporting a roller. On these rollers, as shown, is mounted a bar provided, in turn, with pivots for a second long roller. On this the work rests. It will be seen that this

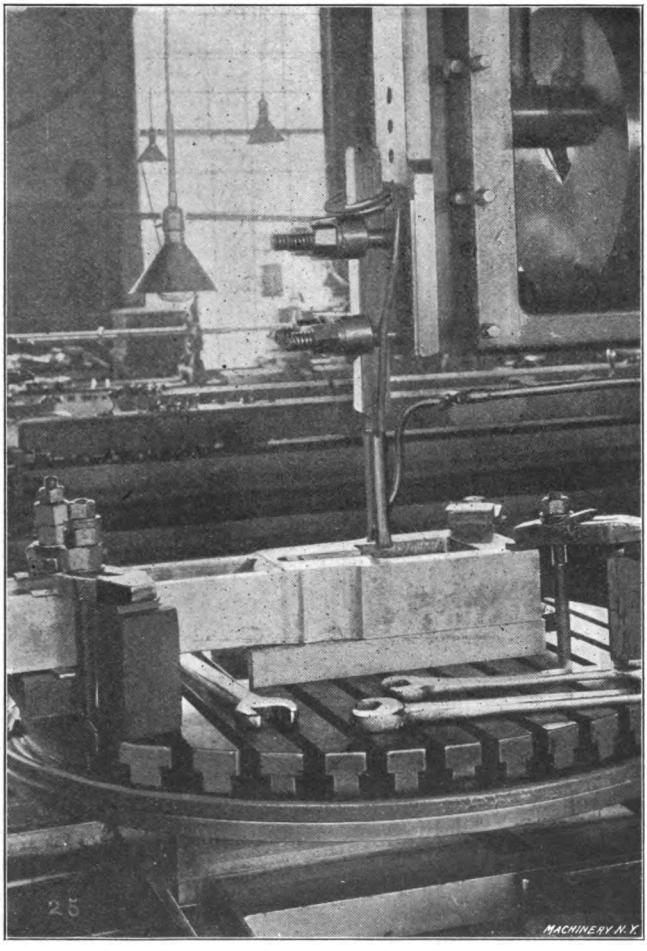


Fig. 14. Working out the Opening at the Cross-head End of the Main Rod

arrangement allows the work-table of the slotting machine to be fed or adjusted in and out, or from one side to the other, without any interference to this movement from the support of the outer end. The work will roll freely in and out on the long upper roller, and the bar on which that roller is mounted will roll freely from side to side on the rollers mounted in the screws supported by the trestle.

After finishing out the openings as just described, the rod is taken to the drill press, where the holes for the two ends of the key-slot are drilled, as shown in Fig. 13. Fig. 15 shows this slot being worked out with a tool similar to that shown in Fig. 14. A key-block, such as is used in the finished rod, is mounted between the two ends of the jaws, as shown, to take the strain of the cutting and the clamping

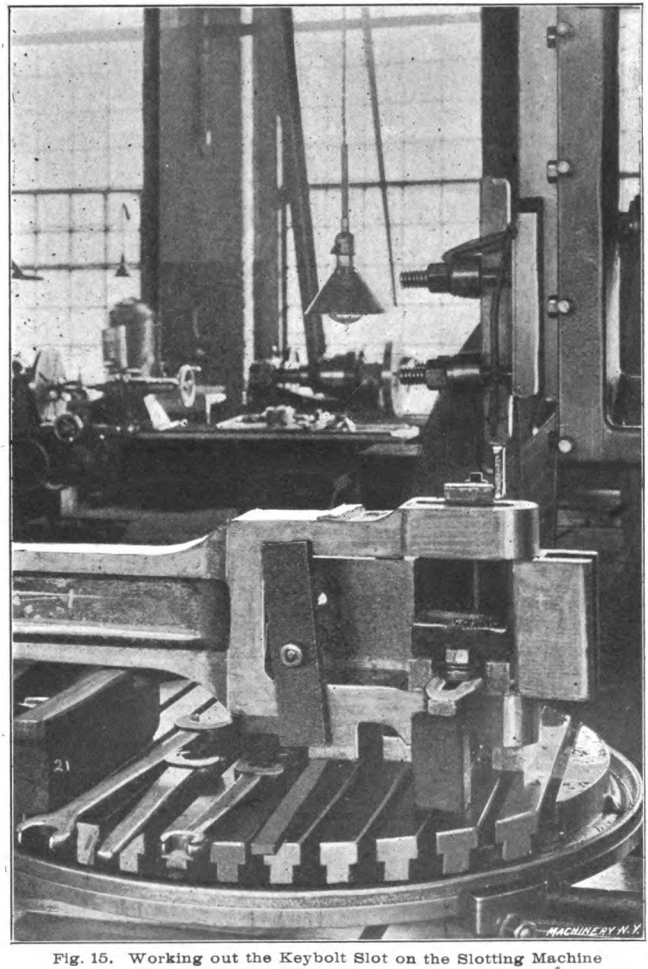


Fig. 15. Working out the Keybolt Slot on the Slotting Machine

in place so as not to spring the work. The outer end is supported as in Fig. 12.

In the next operation the oil holes are drilled and counterbored and the oil cup at the small end is worked out. This is rounded, as shown in Fig. 3. The oil cup at the large end is not rounded at the present time, as it is there shown, but is left in the shape of a

rectangular block the full width of the head as seen in Fig. 20. The only reason for rounding this oil cup would be to effect a slight saving in weight and appearance. It does not appear that the slight advantage is sufficient to warrant the cost of the operation.

The rod is now finished so far as the machining operations are concerned, and is in the condition shown in Fig. 16, where its weight

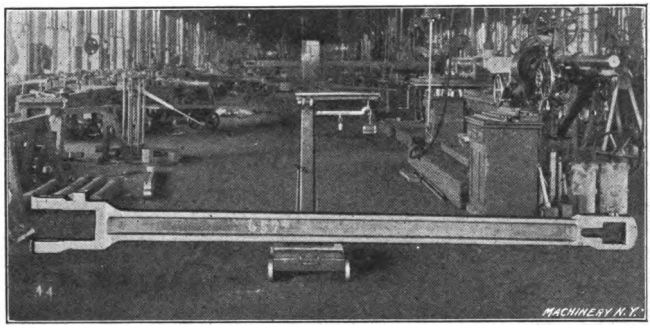


Fig. 16. The Main Rod at the Completion of the Machine Work

is shown to be 657 pounds. This, it will be seen, is only one-third of the rough weight of the forging as given in Fig. 4. This is an interesting example of the efficiency of modern machining operations. It would be possible to forge the blank much closer to size than is done in actual practice, so that the amount of metal removed could

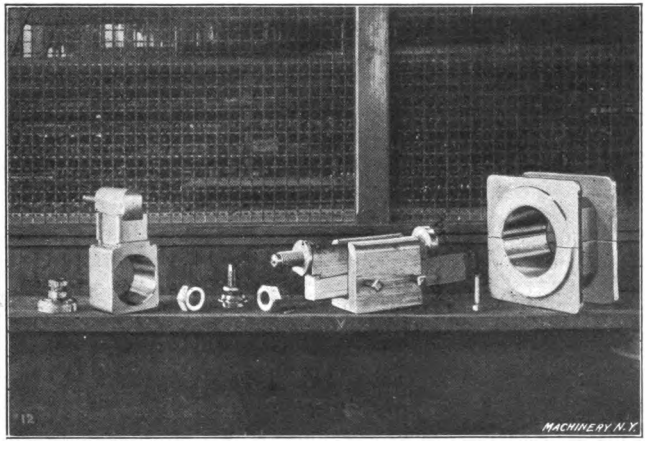


Fig. 17. The Brasses, Liners, Gibs, Bolts, etc., to be fitted into the Main Rod

be greatly lessened. It is so simple a matter, however, to remove large quantities of metal with rigid machines and suitable tools, that there is no economy in taking the time required to forge close to size. As a consequence, twice as much metal is cut off and thrown into the scrap as is left in the finished part.

Bench Work on the Main Rod

The main rod now goes to the bench and vise operators, where it is polished and fitted to the parts that go with it, shown in Fig 17. The polishing is done (see Figs. 18 and 19) by emery wheels hung

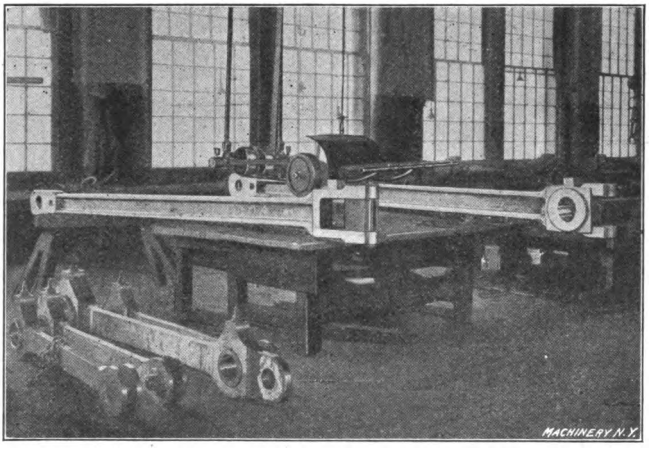


Fig. 18. Suspended Emery Grinder used for Finishing

on counterbalanced swinging frames from the ceiling. These have entirely supplanted the laborious and time-consuming filing operations that used to be employed. The wheels can be manipulated so as

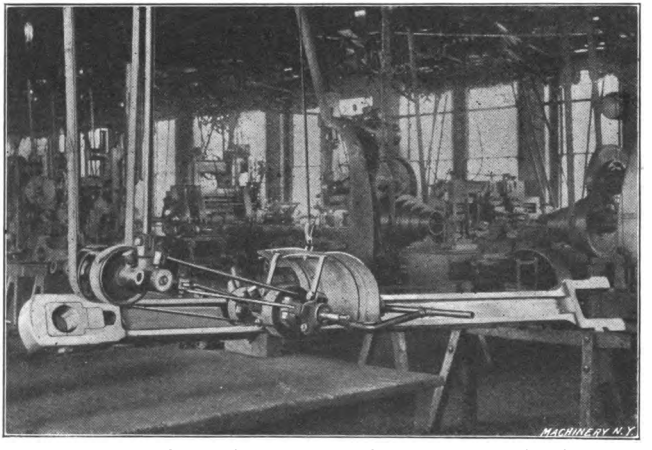


Fig. 19. Grinding and Polishing the Channels on the Main Rod with Suspended Grinder

to follow flat and round surfaces with equal facility, smoothing out all the roughness of the outlining operations on the heavy milling machines. Fig. 18 shows the wheels smoothing up the round for the swell of the head at the open end. Fig. 19 shows a small wheel

with a rounded edge finishing up the corner of the groove in the channel.

In addition to these polishing and finishing operations, the parts shown in Fig. 17 have to be fitted into place. The machine work done is of such a grade that no machine operations are required for fitting these pieces. A little easing with the file and the vise here and there is all that is required. The parts themselves and their uses in the rod will be readily understood by reference to Fig. 3. Fig. 20 shows the completed rod on the scales.

Design of the Side Rods

Fig. 28 shows the type of end rod, and Fig. 22 the intermediate side rod used on these consolidation locomotives. Owing to the short center distances between the crankpins, the inertia of the rod as it flies up and down is not so serious a matter as in the case of the main rod. For this reason, it may economically be made of a plain rectangular section as shown. Solid bushings are used, with no pro-

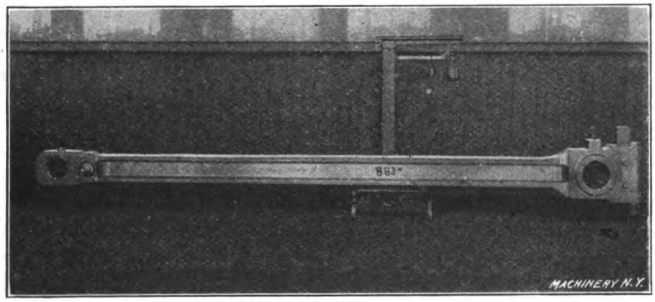


Fig. 20. The Main Rod ready for the Locomotive

vision for adjusting. When these are worn to a point where further use becomes inadvisable, they are pressed out and replaced with new ones taken from stock. Forked pivot-hinges are provided to which the end rods are connected with a knuckle joint, as shown best in Figs. 22 and 34. This is the usual construction for consolidation locomotives. Owing to the inequalities of the track and unequal wear of the driving wheel tires, there can be no assurance that the driving wheel axles will remain in the same plane, so it is necessary to hinge these rods to give a free vertical movement for the axles with relation to each other.

Split boxes have sometimes been provided for the crankpin bearing for one of the end rods, either the front or back, but this is not now done on this road. Adjustment of center distances is rendered unnecessary at the present time by the exceedingly careful attention to dimensions given in the shop. In machining and inspecting, the distances between the finished surfaces of the frame pedestals of the driving boxes are required to come right within the thickness of a piece of paper, which (as any mechanic knows) is somewhere near 0.005 or 0.006 inch at the most. Under such conditions, end adjust-

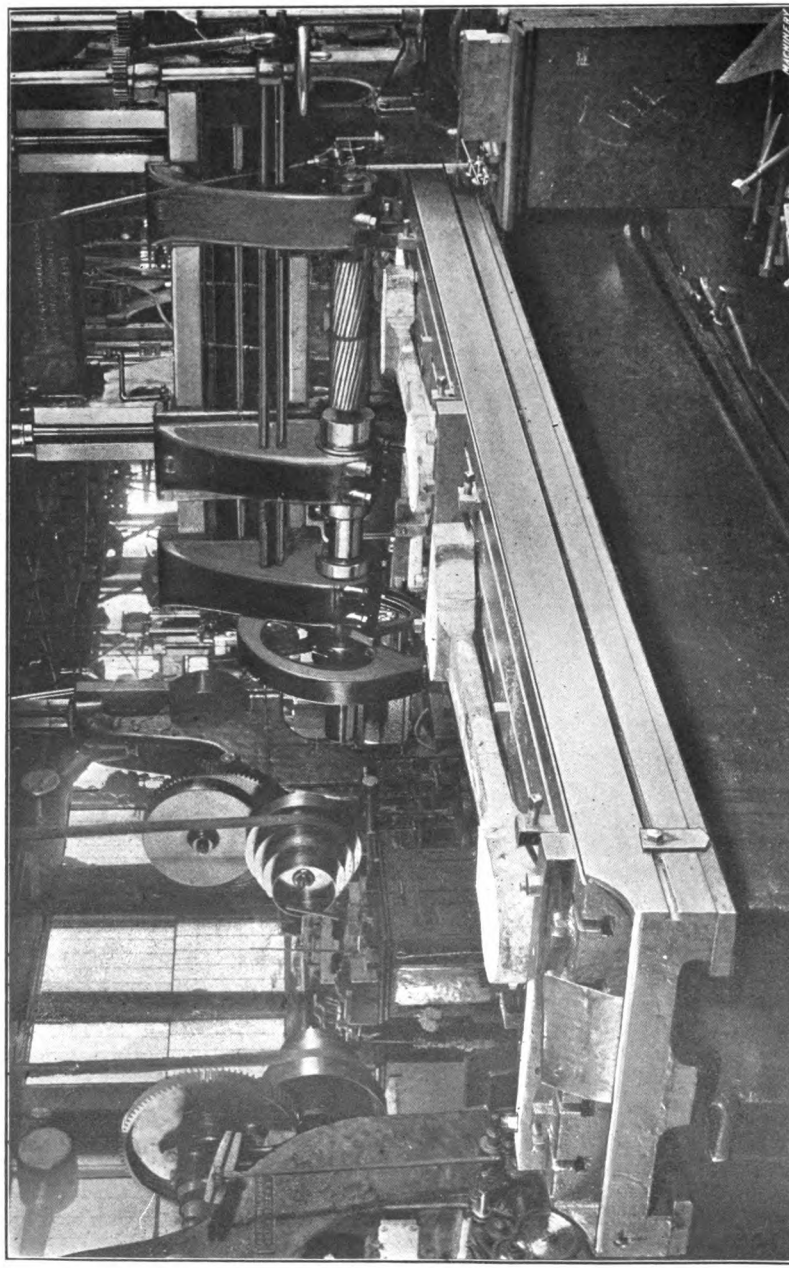


Fig. 21. Finishing the Sides of the Heads of the End Rods

ment becomes unnecessary. Such variation in center distances as results from wear affects alike the axle boxes and the crankpin bearing.

Removing the Metal from the Rod Forgings and Laying them out with Templet

In Fig. 21 is shown the first machining operation on the end rod. Two or four of these at a time are laid on the bed of the planer-type slab milling machine, while the side surfaces of the stub ends are worked off on one side. The forgings have, of course, been packed on the machine so as to rest firmly, and the depth of cut is so gaged as to leave stock to finish out on both the heads and the rectangular sections. The holding of the work is effected by the means common in planer practice, which have been found sufficient for the heaviest

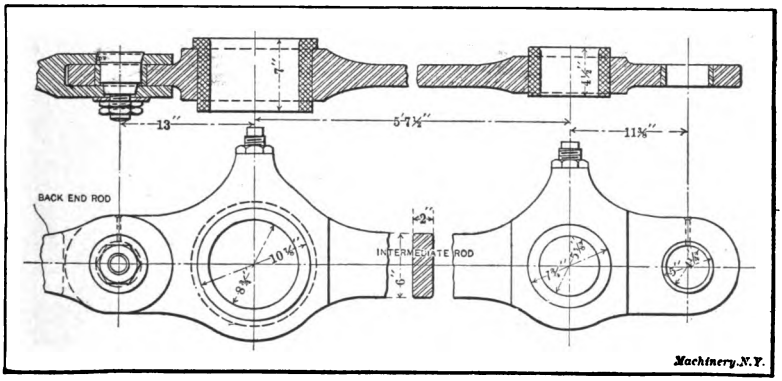


Fig. 22. Intermediate Side Rod

cuts on the slab milling machine. Of course the principal strain is against the back stops, and these, it will be seen, are of very heavy construction.

After milling both heads in the manner just described, these end rods are turned over to the templet man, who scribes out on them the outline, the location of the holes, etc., the same as was done for the main rod. They are then returned to the slab milling machine and milled on the top and bottom edges of the rectangular section and around the outlines of the heads, as described for the main rod in connection with Fig. 10, and as illustrated for the intermediate rod in Fig. 30. The templets for laying out these parts are shown lying beside the base of the milling machine in Fig. 23. One of them is for the front end rod and the other one for the rear, practically the only difference between the two being a slight variation in length.

Fig. 23 also shows the next machining operation, which is that of milling the sides of the rectangular section of the end rod. Four of these are mounted in the miller at a time, two cutters being used on the machine spindle. Substantial stops are provided, as shown, for the end-thrust, while the work is held to the table by straps which

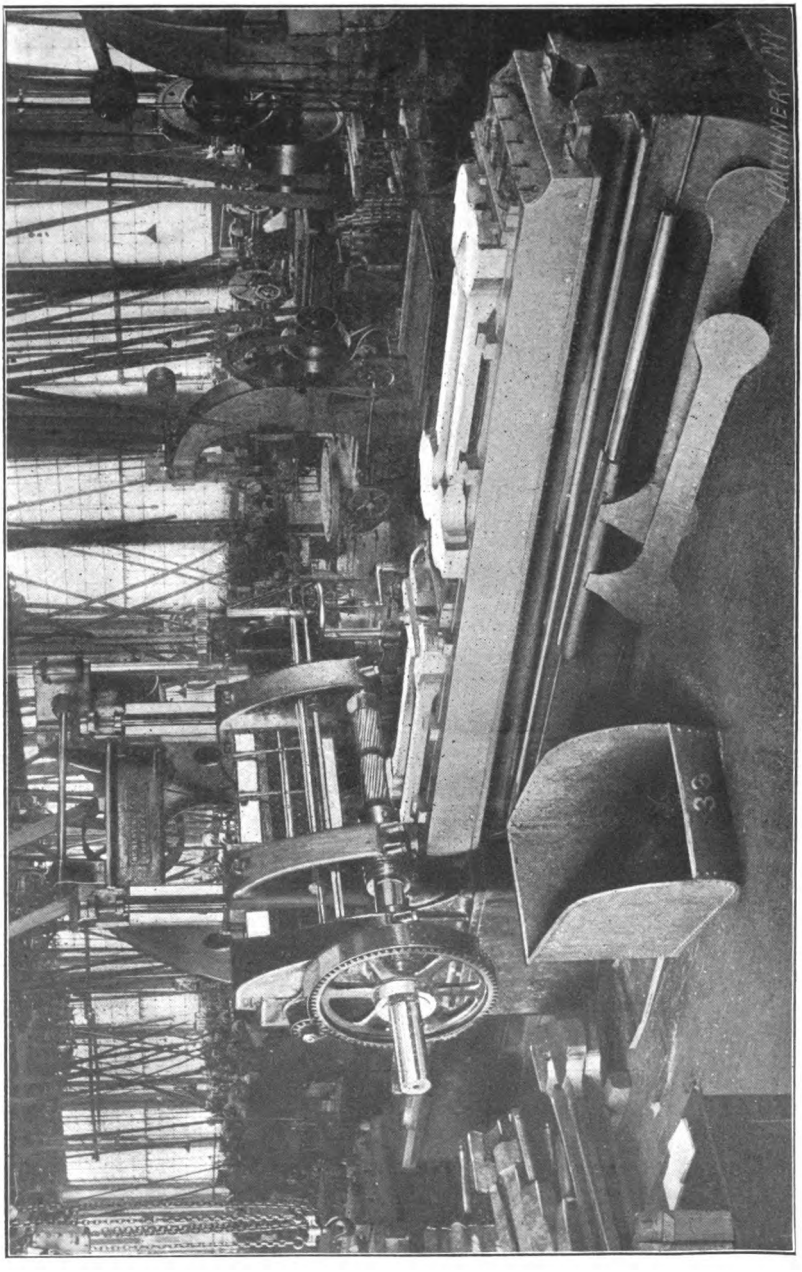


Fig. 23. Finishing the Sides of the End Rods in a Slab Milling Machine

are moved as may be required to permit the passing of the cutters. After one side is completed, the rods are turned over and the other side of the section is milled.

Working out the Holes and Openings

The next operation is that of drilling the hole which forms the bottom of the cut made by the double sawing machine, in forming

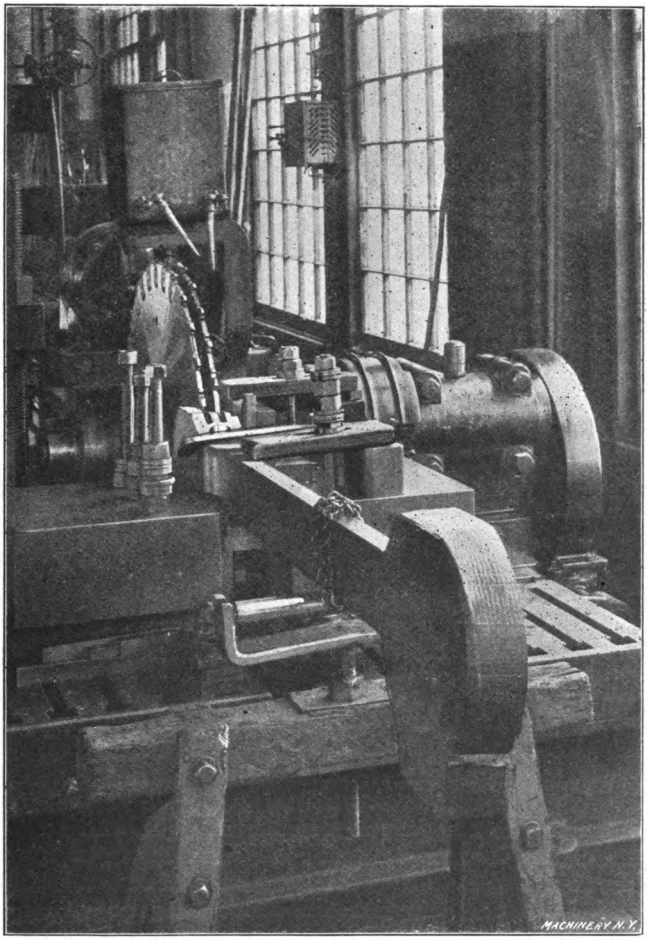


Fig. 24. Cutting out the Knuckle-joint Slot in the End Rod

the slot for the hinged connection with the intermediate rod. The saws are shown cutting into this hole in Fig. 24. This is the same machine as shown previously in Fig. 9, at work on the main rods. The outer end of the work is supported on a roller mounted on a screw-jack and trestle for convenience in setting the work.

This is not required for the feed of the machine, which is applied to the saw-slide instead of the work-table.

The slot thus roughed out has next to be finished. This operation, shown in Fig. 25, is done on the slotting machine with the same arrangement of tools and fixtures as used on the main-rod operations shown in Fig. 12. The roller support for the outer end of the work is here shown to better advantage.

It will be noted by reference to Fig. 28 that these slots are tapered in to the center line of the hole, and have parallel sides from there to the bottom. This taper is comparatively slight, being only 1/16 inch in the whole distance. The tongue of the intermediate rod which enters this groove is similarly tapered at the outer end, and parallel at the inner end. This provides for a slight lateral flexibility in the separate members of the system of the rods. This is a very necessary provision, as it is not practicable to fit the driving wheel axles

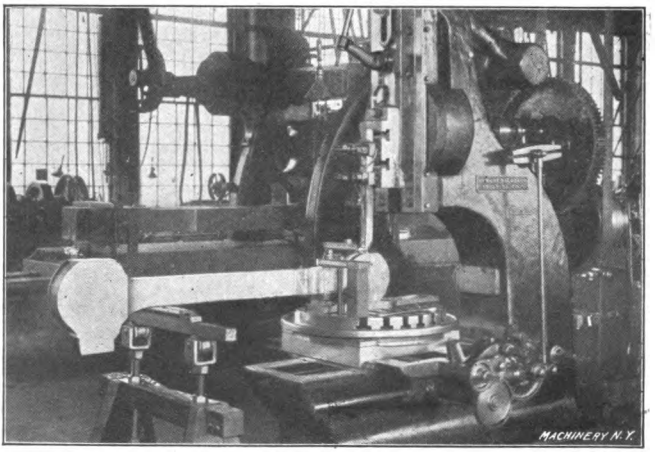


Fig. 25. Machining the Knuckle-joint Slot for the End Rod in the Slotting Machine

without end play, nor is it possible to keep them so fitted after they have been in service for a while. The circular table of the slotting machine comes into play in the cutting of the tapered portions of the slot. It is turned slightly to the right for one side of the slot, and slightly to the left for the other side, permitting the whole slot to be machined without shifting the work on the table.

The next operation is a very interesting one. It is that of cutting out the stock for the crankpin holes. These holes are not cut out of the solid, the operation being rather one of trepanning, as it has sometimes been called from its resemblance to the surgical operation occasionally performed on damaged skulls. The work is strapped to the platen of a special vertical double spindle boring machine, as shown in Fig. 26. This machine is powerfully driven by a motor at each end of the main shaft, and is provided with suitable feeds and speeds for rapid work in tough materials. The speed changes are

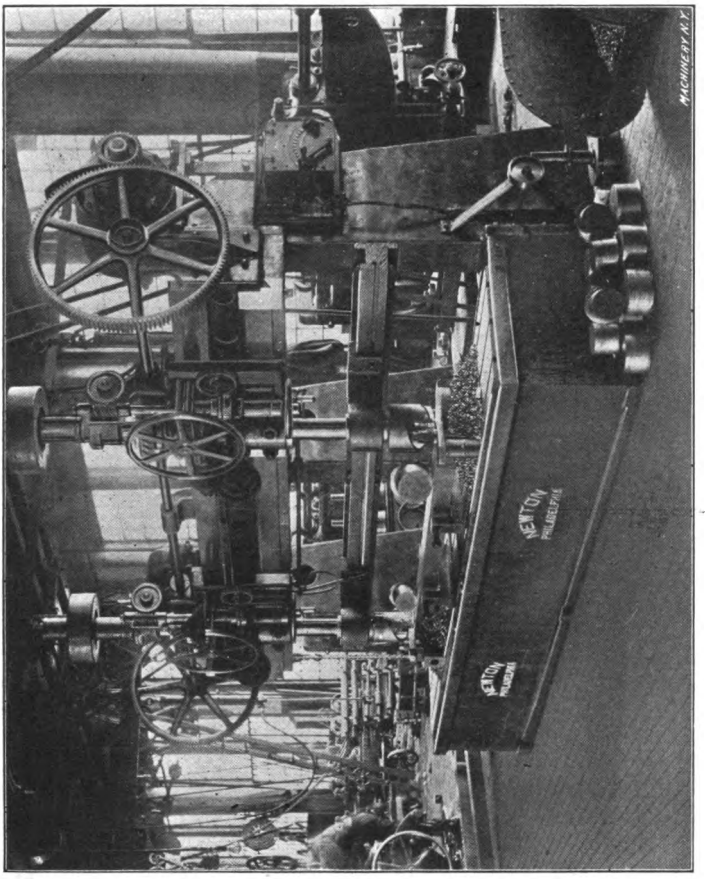


Fig. 26. Cutting the Crank-pin and Knuckle-pin Holes in the End Rod in a Double-spindle Newton Boring Machine

effected by variable speed motor control, while the changes in feed are made by a positive quick change gear device. As shown in the engraving, the tool removes a solid plug of metal from the hole, it being necessary to expend only the power required for removing a comparatively thin chip between this plug and the solid wall of metal in the work. Some of the removed plugs are shown in the engraving, lying on the rod, and piled at the end of the machine.

The style of tool used is shown in Fig. 27. As may be seen, two inserted cutting blades are used, mounted in a cast head of such form as to provide a strong support and at the same time to give ample chip room—a matter of importance in a cut of this kind. Each blade is located by a tongue resting in a groove cut in the holder. It is held in place by tap bolts passing through slotted holes, and an end adjustment is provided by set-screws passing through to the top of the holder. This permits the two blades to be set so that each does its share of the work.

The time required to cut out a plug for the 9⅞-inch hole in the end rod in 50-point steel, 4 inches thick, is approximately 22 minutes. The capacity of the machine was considerably increased by the support given to the spindles close down to the work. This was designed and added to the machine in the shop. As may be seen, these supports

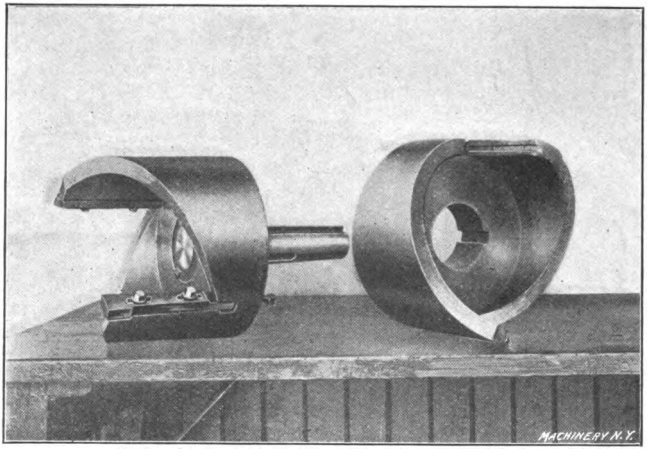


Fig. 27. Type of Tools used in the Operation shown in Fig. 26; these tools remove a Solid Core from the Hole

are adjustable lengthwise to follow the spindles in whatever position the latter may be placed. Another convenience is the stops provided on the cross-rail for locating the heads. These clamp firmly on the

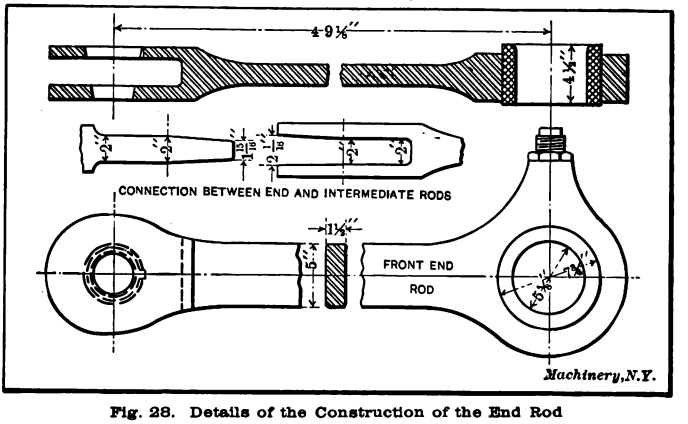


Fig. 28. Details of the Construction of the End Rod

lower V of the guiding surface and are adjustable to any position. By means of them the heads may be shifted from one definite position to another, so that the four holes met with on the intermediate rods (as will be described later) are bored without taking measurements on any except the first pieces set up. The holes in the rods thus

roughed out are finished in the same machine with suitable boring tools and reamers.

While the outline of the end rods has been in part roughed out on the milling machine, so much of this is circular as to permit its being finished very nicely on the vertical miller in the way shown in Fig. 29. The work is clamped in place on the circular table on

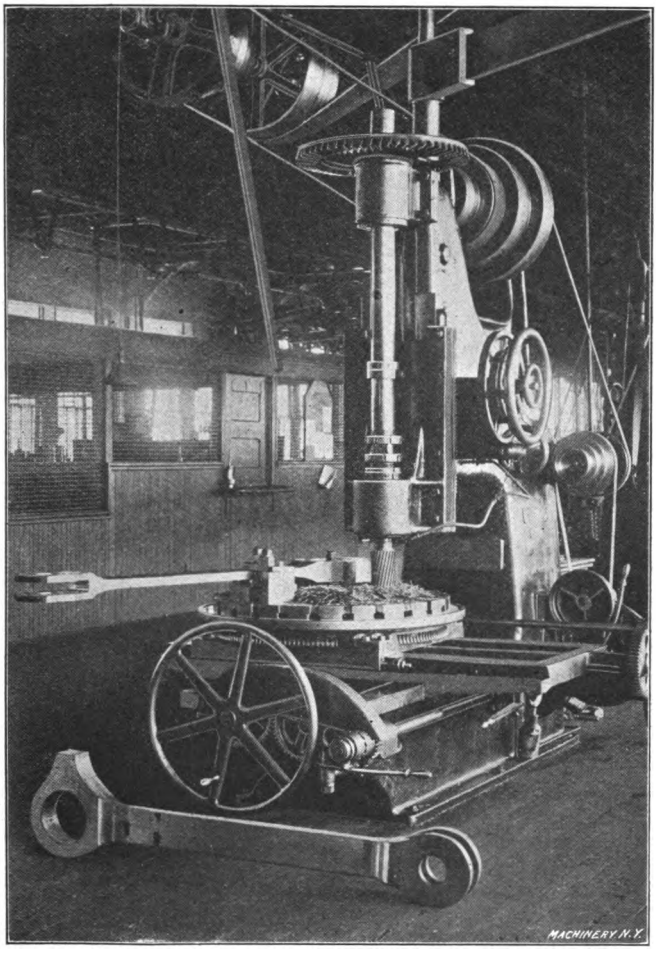


Fig. 29. Machining Circular Outlines of the End Rod on the Vertical Milling Machine with Rotary Table

the axis, first of the crankpin, and then of the knuckle-pin, while the contour in each cut is finished to the proper radius by the circular feed. On this same machine the remaining non-circular portions of the outline are worked out by hand in a way similar to that described for the main rod on the horizontal miller.

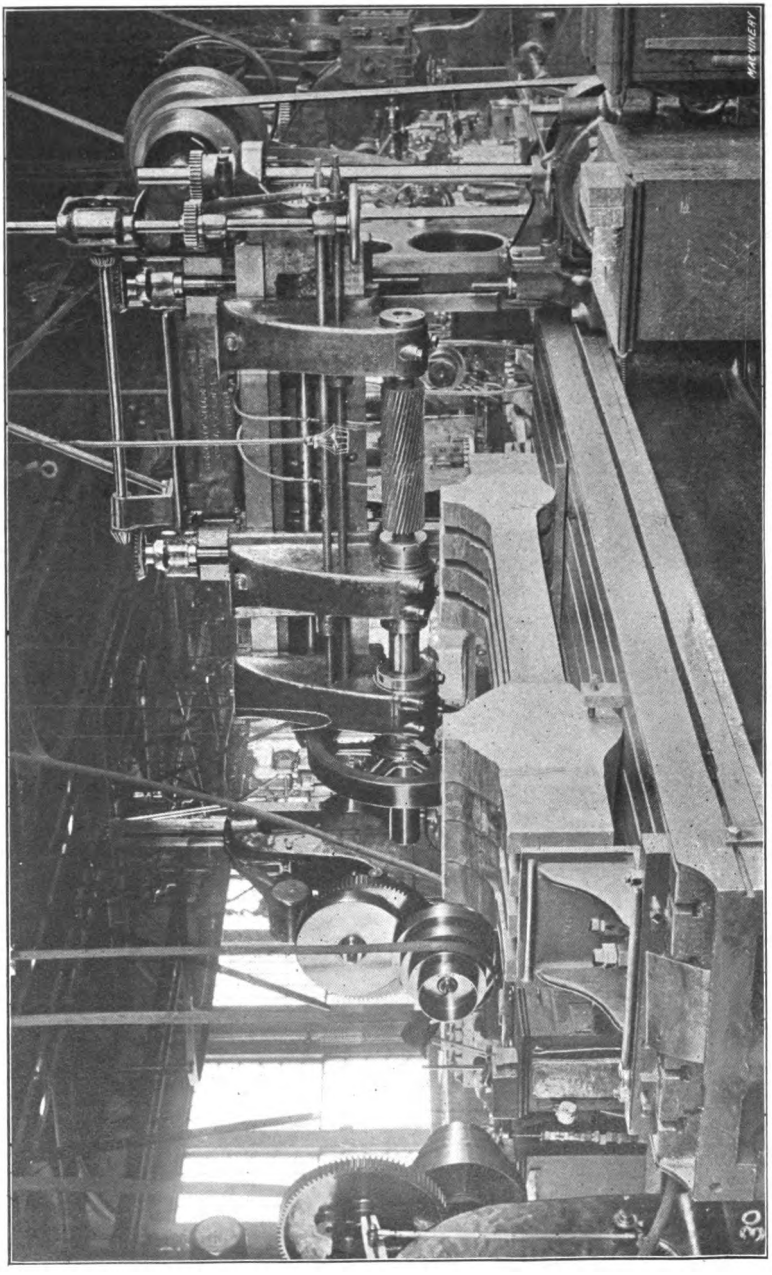


Fig. 30. Cutting the Edges and Outlining the Heads of the Intermediate Rods on the Slab Milling Machine

The subsequent operations for this piece resemble similar operations on the main and intermediate rods, so special reference will not be made to them. These operations include the drilling, counterboring, tapping, etc., of the oil holes, the polishing and finishing of the surfaces, the fitting of the brasses, etc.

Operations on the Intermediate Side Rod

The details of the intermediate rod are shown in Fig. 22. This has the same rectangular sections as the end rod, and requires solid bushings, simply pressed in place. The holes in the tongue for the knuckle-pin, connecting it with the end rods, are bushed with case-hardened and ground steel, bearing on a pin which is treated in the same way.

The operations are the same as for the end rods, up to and including the milling of the upper and lower surfaces of the rectangu-

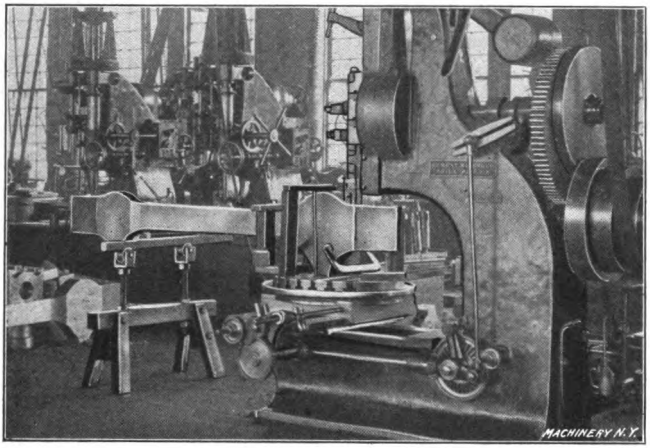


Fig. 31. Finishing the Sides of the Tongue for the Knuckle-joint on the Intermediate Rod in the Slotting Machine

lar sections. Owing to the fact that there is comparatively little circular outline around the main crank-pin bosses, these are worked out on the slab milling machine by the vertical adjustment of the cross-rail by the operator as shown in Fig. 30, the operation being similar to that described for the main rods. The engraving shows the work set in place in the machine, but not yet clamped down. Care is taken in setting the work to have the outlines scribed by the templet come at the same height at each forging, so that the workman can do four at once and follow only one outline.

The next operation is the finishing of the sides of the tongues, where they fit into the slot in the knuckle-joint of the end rods, This is done in the slotter with a tool-holder which permits the blade to be relieved on the back stroke. The operation is shown in Fig. 31. The circular table is used as on the end rod to machine the tapered

end of the tongue for the hinged joint. The rolling outboard support and the method of holding the work is plainly shown. The holes for the crankpins and joint-pins are worked out on the boring machine in the same way as shown in Fig. 26. The stops on the cross-rail are used for locating the spindles in shifting them from the crankpin to

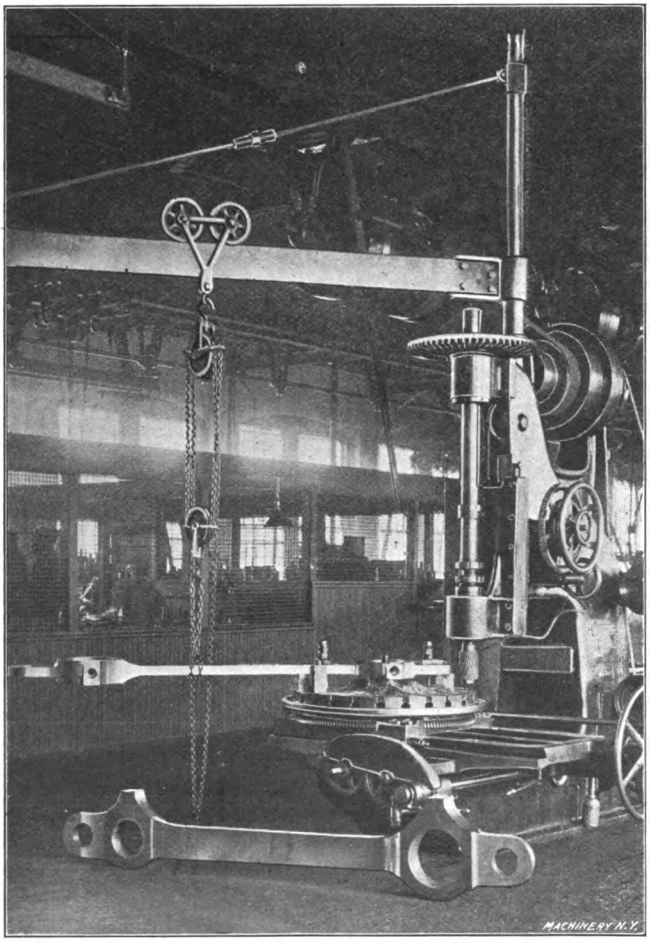


Fig. 32. Milling Circular Outlines in the Intermediate Rods with the Outer End of the Work Supported from a Swinging Arm

the hinge hole, and *vice versa*, making repeated measurements unnecessary.

The finish milling of the circular portion of the outline of the rod is done as shown in Fig. 32 in an operation similar to that shown in Fig. 29. In this case, however, owing to the greater length and weight of the work, it becomes necessary to support it at the outer end.

This is done very handily by a crane swinging from a support on the top of the frame of the machine. While the center of the swing of this crane is not concentric with the axis of the table, it is near enough so that very slight adjustment is required in the length of the chain

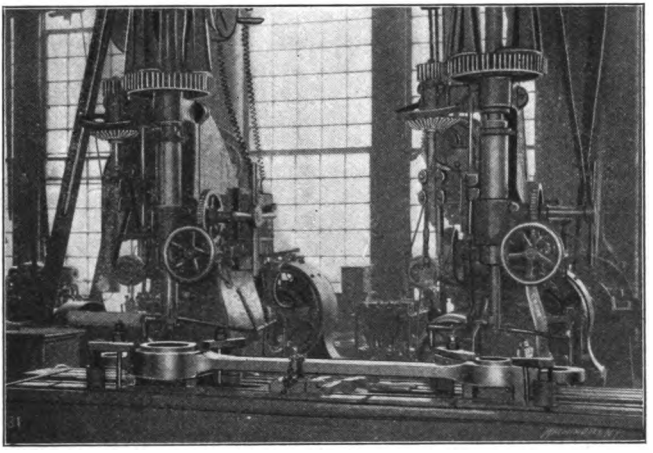


Fig. 33. Re-boring the Bushings in the Intermediate Rods after pressing them into Place

hoist to properly support the outer end, while it is swung around from one side to the other for the circular feed.

The rod is now ready for polishing under the suspended emery wheels previously described, and for having the solid bushings forced into

Fig. 34. Intermediate and End Rods assembled and laid out for Inspection

place. This is done under heavy pressure, so that the bushings are squeezed together slightly, reducing their inside diameter. In order to bring them back to standard size again for the fit on the crank-pins,

the rods are taken to the double-spindle boring machine shown in Fig. 33, where they are re-bored to size. Great care is taken, of course, to preserve the center distance, and to have the new holes exactly concentric with the old ones—that is, with the holes bored in the rod itself.

After the work of machining on the intermediate and end rods has been done, they are all assembled and laid out on horses, as shown in Fig. 34. Here they are inspected for all important dimensions. Rapid and effective work done in the assembling department of this plant demands great accuracy in the dimensions of the parts produced in the shop. This is the final examination of the work for accuracy in these dimensions and it is very carefully done.

Fig. 1 shows the side and main rods at the place of their destination mounted on a "Type H-8-B" freight locomotive, the heaviest engine built by the road. This is of the consolidation type, as shown, and weighs on the drivers 211,000 pounds and on the trucks 27,333 pounds, giving a total weight of 238,333 pounds. The cylinders are 24 inches diameter by 28 stroke, and the wheels are 62 inches in diameter. A boiler pressure of 205 pounds is carried, and the engine develops a tractive force of 42,660 pounds—a very satisfactory figure. In this type of locomotive it is not necessary to pare down the weight, so the parts have been made ample for all the strains that will be imposed on them. The result is a construction which was expected, and has so far proved, to be very durable and serviceable. It is probable that, if heavier freight locomotives are ever required for the road, recourse will be had to the Mallet articulated type.